RESEARCH HIGHLIGHTS

July 2003

Technical Series 03-119

REDUCTION OF AIR INTAKE CONTAMINATION IN HIGH-RISE RESIDENTIAL BUILDINGS

Introduction

Outdoor air is commonly introduced into multi-unit residential buildings (MURBs) via corridor air ventilation systems. Such systems draw air from rooftop locations and deliver it to the corridors of each floor by a vertical ducting system. Outdoor air can also be induced into the corridor air ventilation system at other levels in the building but this is less common. In some newer buildings, outdoor air is ducted directly into each apartment by an in-suite ventilation system. While it is generally assumed that the quality of the outdoor air being drawn into buildings is good, few studies have been undertaken to evaluate the risk of the outdoor air quality being undermined by the presence of exhaust, or venting, systems from adjacent buildings. In many dense urban environments, there is plenty of opportunity for the exhaust emissions from one building to be ingested into the outdoor air intakes of neighbouring buildings.

While the risk of cross-contamination between buildings cannot be completely eliminated, it can be reduced through the strategic placement of both supply intakes and exhausts. Canada Mortgage and Housing Corporation initiated a study, via the External Research Program, to evaluate the reduction of air intake contamination in high-rise residential buildings by way of flow visualization tests in a water channel and tracer gas tests in a wind tunnel. The study evaluated the placement and height of exhaust stacks on buildings as well as the relative locations and physical configurations of the buildings.

Research program

A research project was undertaken to evaluate how the risk of cross-contamination of between neighbouring buildings via exhaust stacks and outdoor air inlet locations could be reduced. The research program consisted of the following experimental methods:

Water flume study

A water flume was used to visualize the emission and dispersion of an contaminant from a rooftop stack on a typical high-rise residential building. The purpose of this task was to identify building configurations that could be conducive to the development of high pollutant concentrations on either the emitting or adjacent building. The tests involved the use of two building models, up to 15 storeys in scale height, located in a suburban environment. Dye was released from the emitting building, and its impingement on both the emitting and neighbouring building was observed. The building heights, widths and proximity to one another were varied to assess their relative impact on the impingement of the dye on both buildings. Based on the results of the water flume tests, a number of building configurations were selected for more detailed testing via tracer gas dispersion in a wind tunnel.

Wind tunnel testing

Wind tunnel testing was conducted to evaluate the impact of varying the width, height and relative position of neighbouring buildings, wind direction, and stack height and location on the risk of cross-contamination. Other tests were conducted, including one with an isolated emitting building. Tracer gas was emitted from the exhaust stack of the emitting building model. A monitoring system was devised to detect the presence of the tracer gas on both the emitting building and a neighbouring building. This testing allowed for the assessment of the degree to which the exhaust could impinge on the emitting and neighbouring building.

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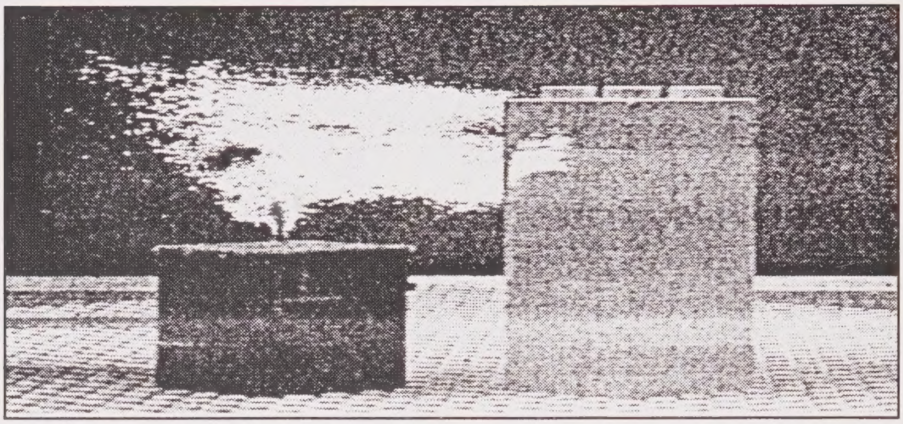


building produced marginal benefits in terms of minimizing the potential for exhaust emission contamination of air intakes located on either building. However, raising the stack height above the height of the upwind building was found to lower the potential for cross-contamination. For emitting buildings located upwind of taller buildings, the testing found that the emission stack height should be no less than the roof height of the downstream building should that building have operable windows or air intakes on its windward side.

Findings

Water flume evaluation

The testing found that for an isolated, 15 storey building, the emission plume from a rooftop stack would not make contact with the building under design wind conditions. However, significant changes in plume behaviour were noted when a taller building was placed either upwind or downwind from the emitting building. Where a building of twice the height of the emitting building was located in close proximity downwind of the emitting building, most of the emission plume was carried downwind but some of the pollutant emission was drawn back to the leeward wall of the emitting building.

Pollutant emissions may be problematic near the top of the leeward wall of the emitting building and at a height equivalent to the height of the emitting building on the downwind building. If the downwind building width is increased, pollutant emissions would be even more likely to become trapped between the two buildings, where they could be reintroduced to either building were fresh air intakes located in this area. For the case where an emitting building is located immediately downwind of a taller building, the exhaust plume tends to rise vertically from the emitting building but can impinge on the leeward wall of the taller upwind building due to the presence of a protected, negative pressure zone that forms in its wake. Similar results were obtained for a situation where wind was directed at the model building at an angle of 45 degrees.

Wind tunnel evaluation

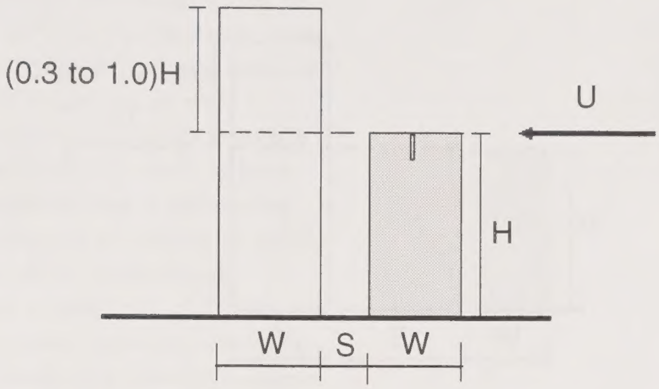
In general, for the situations where emitting buildings are downwind of a close, taller, upwind building, it was found that raising the exhaust stack height on the downwind

Stack location on the roof of the emitting building was found to be important when the emitting building was only partially immersed in the near wake of the upwind building. Pollutant emissions from the emitting building measured on the leeward wall of the upstream building were found to be more diluted when the exhaust stack on the downwind building was located farther away from the upwind building. However, when the emitting building was located fully in the wake of the upwind building, or the emitting building was upwind of an adjacent building, the location of the exhaust stack on the roof of the emitting building had little impact on the dilution of pollutant emissions. The risk of cross-contamination somewhat minimized when the exhaust stack of a downwind emitting building was located close to the edge of the upwind building's wake-however the results could have varied because of the instability of the airflow in this location.

Wind direction was also found to influence the concentration of pollutants at key points on both the emitting and neighbouring buildings. In general, it was found for situations where wind was directed at the buildings on a 45-degree angle, there was less dilution of the exhaust emissions measured at the neighbouring building. This was likely due to the greater building wake caused by the wind's angle of attack. The larger building wake would be more capable of entraining the emission plume from the stack, thereby preventing dilution at the same rate that would be experienced when the wind direction was normal to the building orientation.

Based on the testing, design criteria were developed to minimize the risk of cross contamination between building exhaust and air intakes. The criteria are summarized in Tables 1 and 2.

Table 1: Guidelines for an emitting building upwind of taller, adjacent building

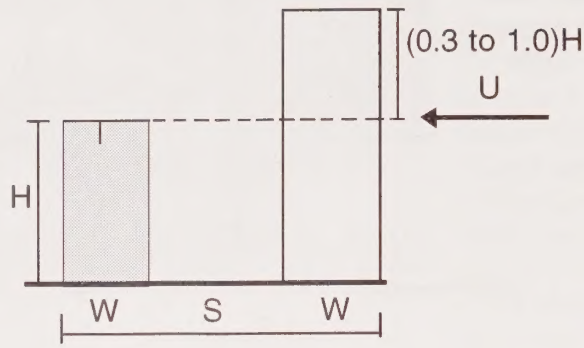


Configuration	Description	Region of plume contact	Possible mitigation measures
A1	$\Delta H > 20m$ S = 0 (no gap)	base of windward wall of adjacent building	a) operable windows should not be placed on adjacent building's windward wall, b) fresh air intake of adjacent building should be placed near the roof (preferably not on windward wall)
A2	$\Delta H < 20$ m S = 0 (no gap)	windward wall of adjacent building; location of contact depends on stack height and flow rate	a) operable windows should not be placed on adjacent building's windward wall, b) fresh air intake should not be placed on windward wall of adjacent building, c) increase stack height or flow rate so that plume travels over roof of adjacent building
A3	$\Delta H > 20m$) S < 30m (small gap)	base of windward wall of adjacent building; leeward wall of emitting building	a) operable windows should not be placed on adjacent building's windward wall or leeward wall of emitting building b) fresh air intake of adjacent building's should be placed near the roof (preferably not on windward wall), c) fresh air intake of emitting building should not be placed on leeward wall
A4	$\Delta H < 20m$ S < 30m (small gap)	windward wall of adjacent building; location of contact depends on stack height and flow rate	a) operable windows should not be placed on adjacent building's windward wall, b) fresh air intake should not be placed on windward wall, c) increase stack height or flow rate so that plume travels over roof of adjacent building

NB: Minimum plume height = $h_s + (hr)min = h_s + 4.5d$, where h_s is the stack height, d is the stack diameter and h_r is the plume rise. For small ΔH (<20 m), h_s can be set such that the plume travels above the adjacent building.

It should be noted that the guidelines detailed in Tables 1 and 2 are based on the objective of minimizing the opportunity of cross-contamination. The guidelines are not based on any assessment of the actual risk associated with the reintroduction of the diluted emissions at potential air intake locations to the occupants of the buildings.

Table 2: Guidelines for an emitting building downwind of taller building



Configuration	Description	Region of plume contact	Possible mitigation measures
B1	$\Delta H > 20m$, S = 0 (no gap)	leeward wall of adjacent building	operable windows or intakes should not be placed on adjacent building's leeward wall,
B2	$\Delta H < 20m$; S = 0 (no gap)	leeward wall of adjacent building	a) operable windows or intakes should not be placed on adjacent building's leeward wall, b) increase stack height or flow rate so that plume escapes recirculation zone behind adjacent building
B3	$\Delta H > 20m$ S < 30m (small gap)	leeward wall of adjacent building; windward wall of emitting building	a) operable windows and intakes should not be placed on adjacent building's leeward wall or windward wall of emitting building
B4	$\Delta H < 20m$ S < 30 m (small gap)	leeward wall of adjacent building location of contact depends on stack height and flow rate	a) operable windows and intakes should not be placed on adjacent building's leeward wall or windward wall of emitting building b) increase stack height or flow rate so that plume travels over roof
B5	$\Delta H > 20$ m 30m < S < 60m (large gap)	occurrence of reingestion depends on width of adjacent building W_a. for large W_a, reingestion may occur	Same as B3
B6	$\Delta H > 20$ m 30m < S < 60m (large gap)	occurrence of reingestion depends on width of adjacent building W_a. for large W_a, reingestion may occur	Same as B4

NB: If the upwind building is narrow, dilution values on its leeward wall can be increased by maximizing the distance between the stack and the wall.

Implications for the housing industry

With ongoing urban intensification efforts occurring in most major cities in Canada, buildings are routinely being constructed in relatively close proximity to one another. The study shows that, in these situations, careful consideration of the placement of both outdoor supply air grilles and building exhaust stacks or vents, in both the planned building project and existing neighbouring buildings, is required to minimize the possibility of indoor air quality problems in any, or all, of the buildings concerned. The study provides a useful set of design criteria that could be used to assess, and help minimize, the potential for cross-contamination problems between buildings.

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Research Report: *Reduction of Air Intake Contamination in High-Rise Residential Buildings*

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This project was funded (or partially funded) by Canada Mortgage and Housing Corporation (CMHC) under the terms of the External Research Program (ERP), an annual research grant competition. The views expressed are the personal views of the author(s) and do not represent the official views of CMHC. For more information on the ERP, please visit the CMHC Web site www.cmhc.ca or contact the Project Officer, Responsive Programs by e-mail at erp@cmhc-schl.gc.ca, or by regular mail: Project Officer, Responsive Programs, External Research Program, Policy and Research Division, Canada Mortgage and Housing Corporation, 700 Montreal Road, Ottawa ON K1A 0P7.

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